Climate Validation of MERRA

Siegfried Schubert, Michael Bosilovich, Michele Rienecker, Max Suarez, Randy Koster, Yehui Chang, Derek Van Pelt, Larry Takacs, Man-Li Wu, Myong-In Lee, Scott Weaver, Junye Chen, Julio Bacmeister, Steve Bloom

and many others in the
Global Modeling and Assimilation Office

5 January 2009
NASA/GSFC
Overview

- Global Climate Variability
- Regional Climate Variability
- Analysis Increments, Budgets and Replay

Results from GEOS-5 2004, 2006 validation runs and some updates using latest available results from MERRA
200 MB Zonal Wind vs EC OPS

Jan 04 (neutral)

Jan 06 (weak La Nina)

04 - 06
U*V* vs EC OPS

Jan 04 (neutral)

Jan 06 (weak La Nina)

04 - 06
TOA LW interannual variation (W/m^2)

CERES ERBE-like

Merra

Merra-CERES

Jan 2004

Jan 2006

Jan 04-06

ave=234.9 std=32.98

ave=239.3 std=36.19

ave=4.407 std=9.114

ave=234.7 std=33.65

ave=239.7 std=36.45

ave=4.971 std=9.017

ave=0.192 std=14.61

ave=-0.37 std=15.49

ave=-0.56 std=8.372
2004 Tropical Precipitation

MERRA

<table>
<thead>
<tr>
<th>Month</th>
<th>Score rms</th>
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<tbody>
<tr>
<td>OCT</td>
<td>3.43</td>
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<tr>
<td></td>
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<td></td>
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<td>1.23</td>
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<td>0.89</td>
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<td>MAR</td>
<td>3.55</td>
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<td>0.85</td>
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<td>1.36</td>
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<td>3.56</td>
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<td>0.88</td>
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<td>JAN</td>
<td>3.48</td>
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<td>0.85</td>
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GPCP

<table>
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<th>Month</th>
<th>Score</th>
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</thead>
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<td>3.01</td>
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<td>JAN</td>
<td>2.86</td>
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</table>

The images show maps of tropical precipitation for different months, with the scores and rms values for MERRA and GPCP datasets.
Taylor diagrams for tropical precipitation. GPCP merged precipitation is the reference data set. The diagrams compare spatial correlation (to GPCP) of the analysis to standard deviation normalized by the reference data set. If a field exactly duplicated GPCP, it would be at the 1,1 point. Linear distance to the 1,1 point is a measure of skill in reproducing the reference data set (annual 1979-2005).
JFM 1998 EL NINO

**Link to Weather**

200mb Height and Precipitation Anomalies

**Link to Ocean**

SST and 850mb Wind Vector Anomalies
Validating 3 hourly Precipitation (Jan04)

MERRA

CMORPH (obs)

mm/day

Thanks to Matt Sapiano
Monthly Mean Precipitation over Americas July 2004 (mm/day)

Difference from GPCP

GEOS-5 reproduces the typical structure of the monsoon rainband. Seasonal march of the rainband is reasonable, with a peak in July.

Maximum rainfall region is located reasonably well in the windward slope of the mountains (the Sierra Madre Occidental).

Southwesterly flows in the Gulf of California and in the upslope of the mountains seem to be benefit from the high-resolution (1/2-degree) data assimilation.
2004 Precipitation Revisited

US-Mexico 1 deg raingauge (CPC)

NAME NERN raingauge (CPC)

NARR

MERRA
Diurnal Cycle

Jul/Aug 2004 v-wind at 35°N

NARR

Day (12 LT)  Night (00 LT)

GEOS-5

Day (12 LT)  Night (00 LT)
Amplitude of Precipitation Diurnal Cycle (24-h harmonic)

- Larger diurnal variability over continents than oceans
- GEOS-5 tends to overestimate the amplitude over continents and underestimate over oceans
Diurnal variation in precipitation over the United States for July 2004 (mm/day). The July mean is removed.
Interception loss / total evaporation: A defining characteristic of local hydrology

Summary of findings:
-- Interception loss ratio is generally smaller in the offline ("realistic") forcing environment than it is in the MERRA environment.
Likely Problem Source: Coincidence of Rainfall and High Solar Radiation

<table>
<thead>
<tr>
<th>Total Rainfall for 10-day period</th>
<th>Amount of that rainfall that can be evaporated using concurrent SW-net</th>
</tr>
</thead>
<tbody>
<tr>
<td>Station obs.</td>
<td>MERRA</td>
</tr>
<tr>
<td>55.3 mm</td>
<td>41.3 mm</td>
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<tr>
<td></td>
<td>0.3 mm</td>
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<tr>
<td></td>
<td>25.3 mm</td>
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</table>
Analysis Increments, Budgets and Replay
GEOS-5 DAS

\[
\left( \frac{\partial q}{\partial t} \right)_{total} = \text{dynamics (adiabatic)} + \text{physics (diabatic)} + \Delta q
\]

Total “observed change” Model predicted change Correction from DAS

03Z 06Z 09Z 12Z 15Z 18Z 21Z 00Z 03Z

- Reanalysis (MERRA)
- Background (model forecast)
- Assimilated analysis (Application of IAU)
- Initial States for Corrector
- Reanalysis Tendencies for Corrector
- Corrector Segment (1- and 3-hrly products)

Budgets: \[
\left( \frac{\partial q}{\partial t} \right)_{total} = \text{dynamics (adiabatic)} + \text{physics (diabatic)} + \Delta q
\]

Mean analysis increment: measure of model’s mismatch with nature

Replay: \[
\Delta q = q(\text{analysis}) - q(\text{first guess})
\]

MERRA, Scout, JRA25, NCEP R2, etc.

GEOS-5 AGCM or coupled model
January 2004 Zonal Mean Specific Humidity

Analysis Increment

24 Hour Forecast Error
January 2002 Zonal Mean Specific Humidity Budget from MERRA

Tendency
Moist Processes
Turbulence
Analysis Increment
Dynamics
Moist+Turb
Moist+Turb+Dyn
Moist+Turb+Dyn+Ana
Residual

Sum of Physical terms
January 2002 Vertical Mean Specific Humidity Budget from MERRA
Replay to Scout Using CGCM
NINO3 SST: Replay Results (red) versus Reynolds Observations

Nino3 SST

Reynolds
CCSM(SC)
SUBSURFACE OCEAN TEMPERATURE (5S-5N, 130E-80W)

REPLAY TO SCOUT ATMOS. ANALYSIS
Summary

• MERRA improves upon many features of existing reanalyses

• Biases generally smaller than climate signals

• Precipitation issues remain: trends; diurnal cycle, summer land

• Comprehensive output suite including analysis increments
  - anticipate novel uses of MERRA to address climate and modeling issues

movie